Bulletin of the Geological Society of Malaysia, Volume 58, December 2012, pp. 9 – 14

Heavy metals profiles in a groundwater system at a solid waste disposal site, Taiping, Perak

Kamarudin Samuding[1]*, Mohd Tadza Abdul Rahman[1], Ismail Abustan[2] & Mohamed Hasnain Isa[3]

[1]Malaysian Nuclear Agency, 43000 Kajang, Selangor, Malaysia
[2]Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia
[3]Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia
*Email address: ksamudin@nuclearmalaysia.gov.my

Abstract: This paper presents the distribution of heavy metals in a groundwater system at a solid waste disposal site in Taiping, Perak. In this study several boreholes were constructed within the solid waste disposal site. Soil samples were collected from the alluvial deposits at 1 m intervals between 6 and 30 m depths from 6 boreholes using a down-hole hammer. The pore water content of the samples and the ground water was extracted in order to determine the concentrations of heavy metals, such as lead (Pb), manganese (Mn), chromium (Cr), iron (Fe), zinc (Zn) and cadmium, (Cd) using the Inductively Couple Plasma Spectrometer (ICP-MS). From the profiling results, the penetration of heavy metals into the groundwater system was obtained. A profile of heavy metal concentrations in the pore water of the core samples at several boreholes within the study area, and heavy metals concentration in groundwater under different conditions were obtained. Some of the heavy metals concentration such as Pb, Mn, Zn and Fe were high. These high concentrations exceed the maximum permissible concentration as specified in the Drinking Water Standard. Based on contour diagrams, the heavy metals can be detected down to 25 m depth towards the southeast of the landfill and appear to be localized.

Keywords: Groundwater, heavy metals, waste disposal site, core soil, pore water

INTRODUCTION

The concentration and the mobility of heavy metals in soils strata and groundwater have been widely studied in the last decades (Alloway, 1990). Although many heavy metals are necessary in small amounts for the normal development of the biological cycles, most of them become toxic at high concentrations. Heavy metals are introduced into the environment through natural phenomena and human activities, such as agricultural practices, transport, industrial activities and waste disposal (Hani, 1990). Unlike organic wastes, heavy metals are non-biodegradable and they can be accumulated in living tissues and causing various diseases and disorders (Wan Ngah & Hanafiah, 2008)

Recently, solid waste is one of the major contributions for the environmental problems in Malaysia. The problem of groundwater contamination by waste disposal site has worsened in Malaysia due to the poor management of the municipal solid wastes (Mohd Tadza *et al*., 1999; Mohd Tadza, 2001). Solid waste disposal sites are well known to release large amounts of hazardous and deleterious chemical (leachate). Leachate is produced primarily in association with precipitation that infiltrates through the refuse and normally results in the migration of leachate into the groundwater zone and pollutes it.

There is little or no monitoring of the extent of leachate infiltration and its movement into the groundwater at waste disposal facilities in Malaysia. Hence, the extent of short and long term contamination of groundwater is unknown. Since the domestic refuse has the potential to pollute the ground water system, there is a need to study the degree of pollution in groundwater and to assess the migration and dispersion potential of pollutant species and their impact on water quality.

This paper presents the study of heavy metals profiles in the groundwater system at the waste disposal site at Taiping, Perak. In this study, soil samples from several boreholes were analyzed for their heavy metals concentrations such Pb, Mn, Cr, Fe, Zn, and Cd.

DESCRIPTION OF THE SITE

The solid waste disposal site is located in Taiping, Perak and covers about 50 acres in area where the geological formation is consisting mainly of alluvium (Engineering & Environmental Consultants, 1993). The landfilling operation was started in 1995 and since then 555,712 metric tons (74,095 metric tons annually) of domestic waste was dumped in that area. The topography in the vicinity of the waste disposal is generally flat and low lying with local elevations at the site ranging from a high of 3.3 m above sea level to a low of 1.8 m. The climate of the area is typical of Peninsular Malaysia climate characterized by uniform temperature (daily mean maximum and minimum of 34°C and 30°C respectively), and high humidity (80% - 90%). This area is one of the wettest areas in Malaysia with average annual rainfall of about 4000 mm. Generally, the regional pattern of groundwater movement is controlled by topography. Hence, as according to the topography and colloidal borescope system, the regional groundwater flow direction is dominantly towards to the south and southeast of the study area (Mohd Tadza *et al*., 2007).

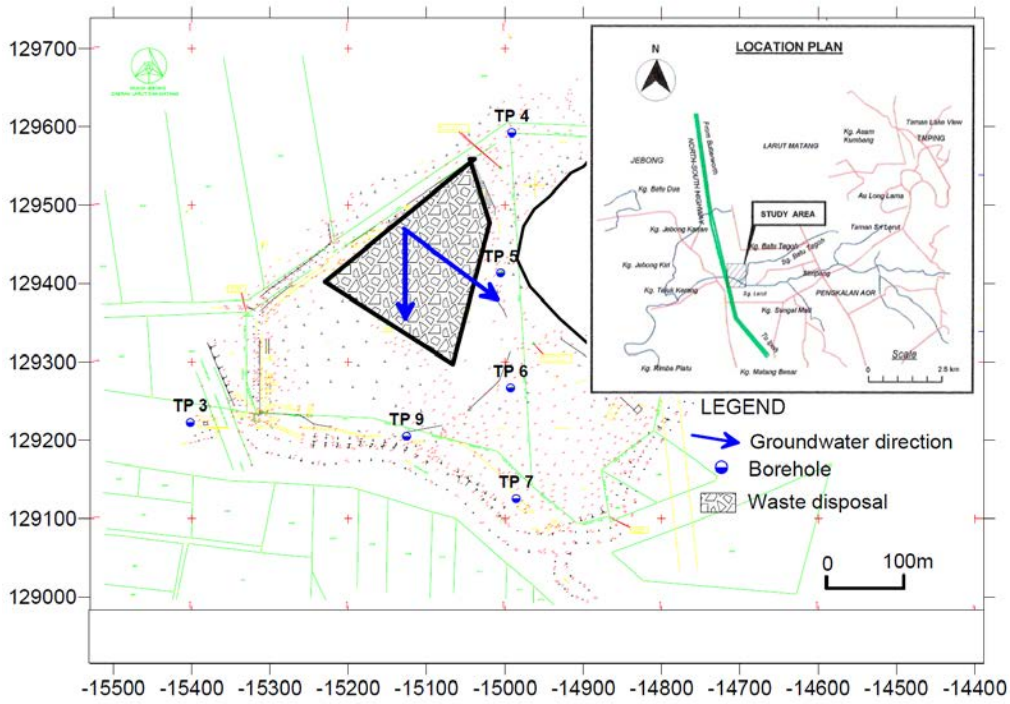

Figure 1: Location of boreholes in the study area.

MATERIALS AND METHODS

Boreholes and soil samples collection

Based on the regional groundwater flow direction, several boreholes have been constructed at the east and south of the waste disposal site (Figure 1). In order to obtain the heavy metals profiles within the study area, 6 sets of soil samples were collected from depths between 1 and 30 m below ground surface at 1 m intervals and sealed in plastic bags for laboratory testing.

The sampling procedure for obtaining continuous soil samples involved collecting a soil core and removing the corer from the borehole, drilling the sampled interval and reinserting the corer and repeating the operation. Drilling and coring were successively carried out for a total of 30 soil cores from each borehole (Engoebumi, 2003).

Measurements and Analysis

Three replicate samples of about 200 g were collected at random from each soil core and brought to the laboratory for chemical analysis. The soil samples were then extracted in order to get their pore water content. The concentrations of the heavy metals in the extracted water samples were determined using a Inductively Coupled Plasma Mass Spectrometry (ICP-MS; Perkin – Elmer Optima 3000) with an auto sampler. The heavy metals profile data was plotted using Surfer and Excel softwares for the interpretation purposes. Quality control and analysis procedures included the analysis of blanks and duplicates, as well as laboratory standard addition methods and laboratory replicates.

RESULTS AND DISCUSSIONS

Heavy metals that were analyzed in this study were lead (Pb), manganese (Mn), chromium (Cr), iron (Fe), zinc (Zn) and cadmium (Cd). The heavy metal concentration profiles were plotted using Excel. Meanwhile, the contour diagrams showing the distribution profile of heavy metals at selected borehole is obtained using Surfer software.

Concentration profile of pollutant species in groundwater

The concentration peaks of the heavy metals were observed throughout the profile at various depths below the soil surface (Figures 2a - 2f). The highest concentration peaks of the Pb, Zn and Cd are detected at borehole TP6 at a depth of between 21 m and 25 m below the ground surface. The highest concentration of the Pb, Zn and Cd were 232.8µg/l, 3390.5µg/l and 13.1µg/l, respectively. These heavy metals concentrations exceed the maximum permissible concentration of the World Health Organization Drinking Water Standard (Appelo and Postma, 1990; Table 1). The high heavy metal contents can be correlated to the leachate flow path indicating that the groundwater in this area has been contaminated by the leachate from the waste disposal site.

The Mn and Fe concentration peaks above the maximum permissible concentration in borehole TP4, TP6 and TP9 at various depths (Figures 1, 2b and 2d). The concentration of Cr in the groundwater profile within the study sites ranges from 0.1µg/l to 18µg/l, which is below the maximum permissible concentration.

Contour diagram of heavy metals distribution in groundwater

Contour diagrams showing solute concentrations were used as the main method of displaying water chemistry profiles, as they allow the visualization of the pattern of the

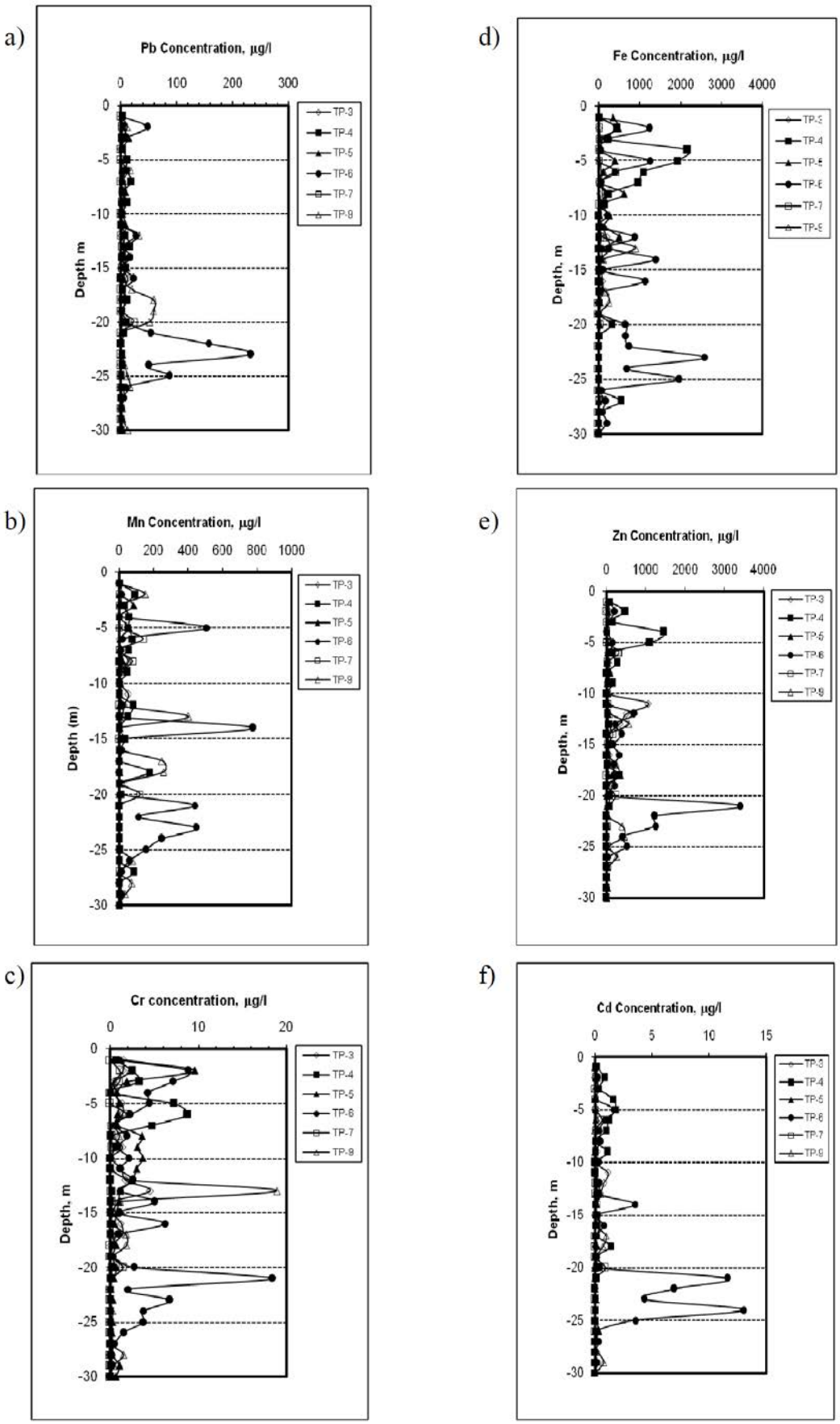

Figure 2: Concentration profile of heavy metals at selected boreholes in the study area (a) Pb , (b) Mn, (c) Cr, (d) Fe, (e) Zn and (f) Cd.

heavy metals plume distribution in the aquifer (Figures 3 and 4). The distribution profile of heavy metals for boreholes TP4, TP5, TP6, TP9 and TP3 (Figure 3) shows that the heavy metals species seem to have concentrated dominantly toward borehole TP6, which is situated at the southeast of the waste disposal site. The contaminant species from the waste disposal site could have migrated and accumulated at TP6. The highest concentration can be detected at a depth of about 25 m. The contour diagram along borehole TP5-TP6-TP7 shows that most of the heavy metals are concentrated within borehole TP6 and did not reach TP7 located near the Sungai Larut. This indicates that the migration and distribution of the contaminants species are localized and not diffused within a wide area.

CONCLUSION

The heavy metals that exceeded the maximum permissible concentration of the World Health Organization Standards for Drinking Water are lead (Pb), manganese (Mn), zinc (Zn), iron (Fe) and Cadmium (Cd).

The concentration of heavy metals is relatively high at borehole TP 6, particularly at the depth of 25 m depth below

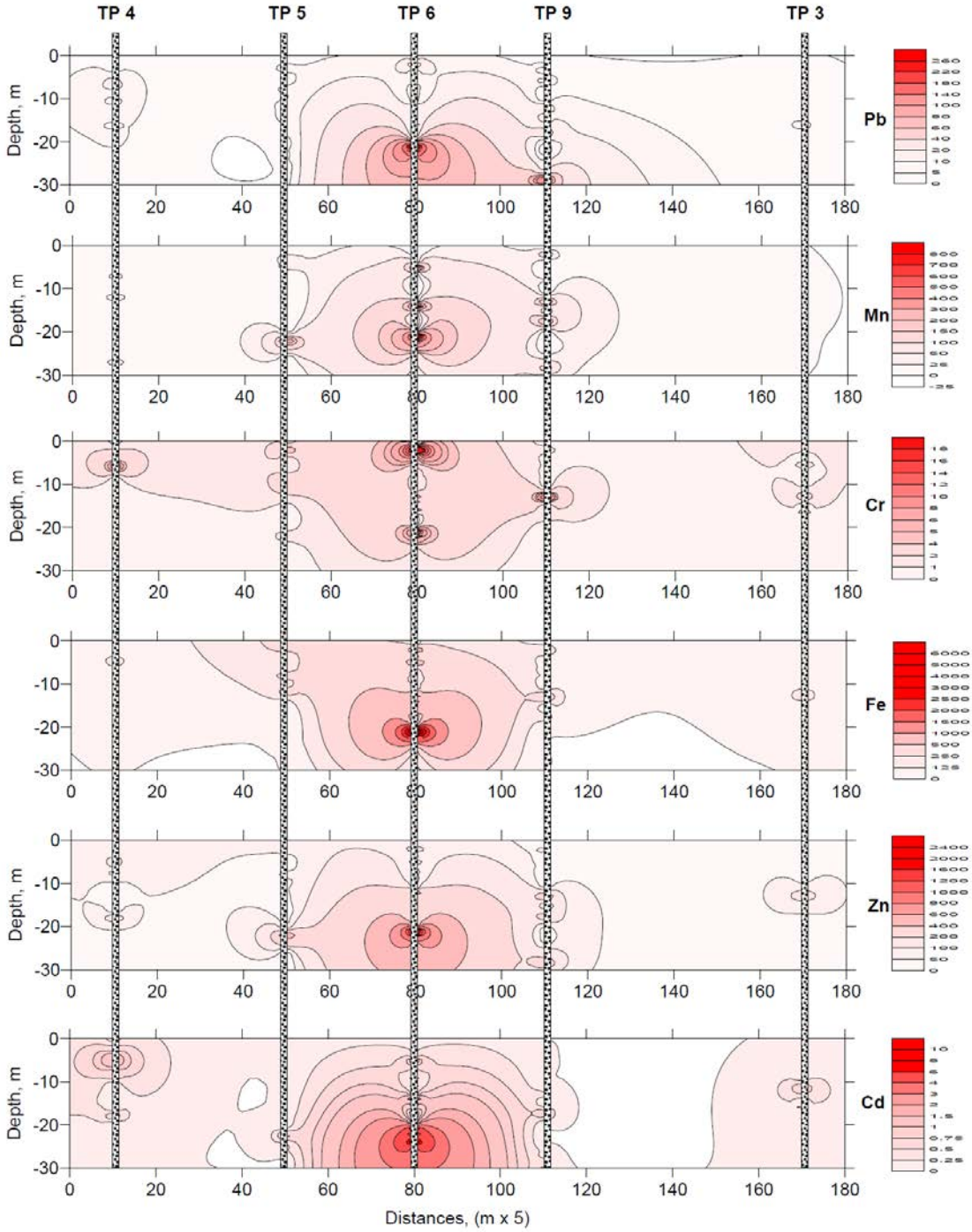

Figure 3: Contour diagrams of heavy metals distribution profile at boreholes TP4- TP5-TP6-TP9-TP3.

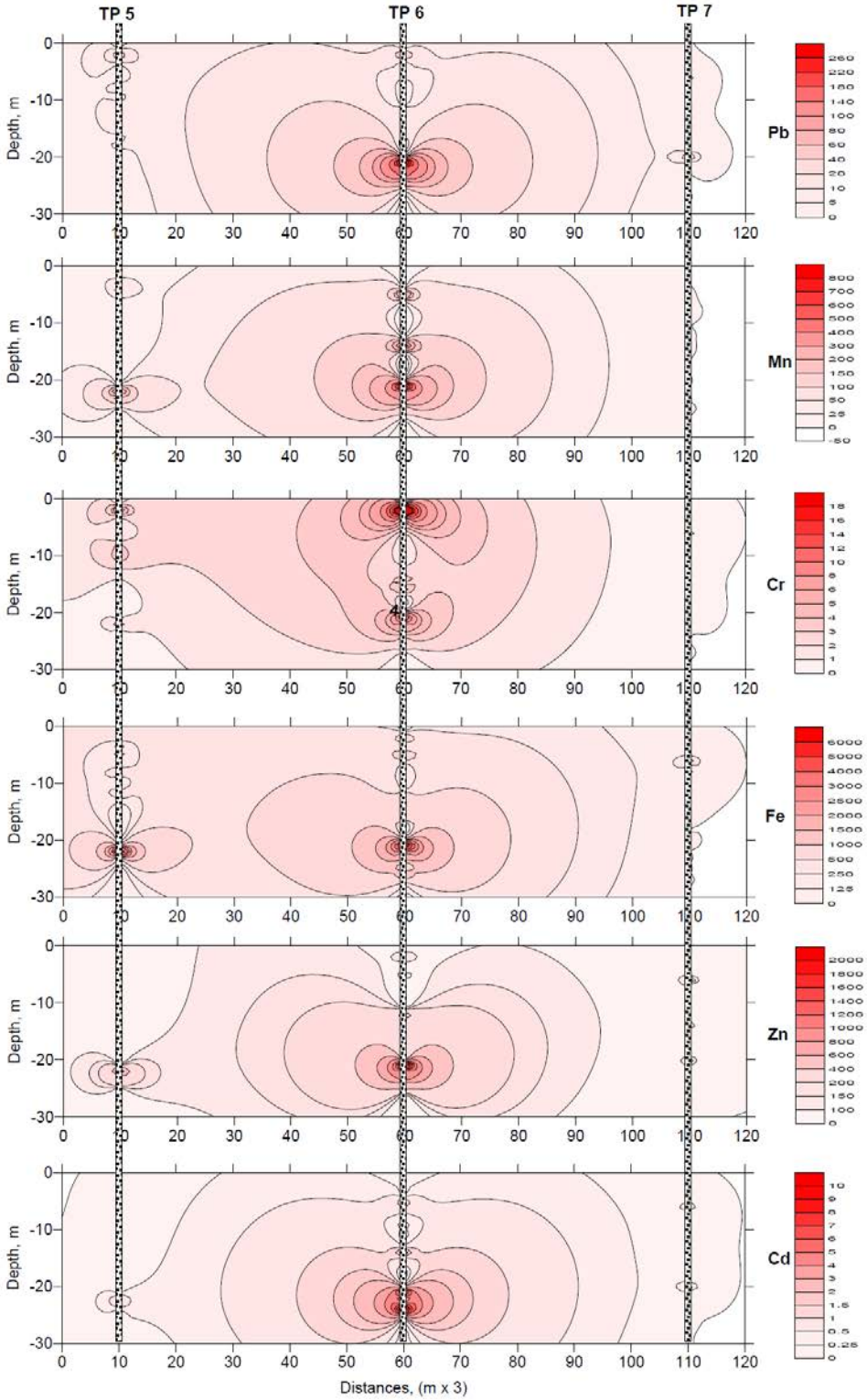

Figure 4: Contour diagrams of heavy metals profile at boreholes TP5-TP6-TP7.

Table 1: World Health Organization Standards for Drinking Water (Appelo and Postma, 1990).

Heavy metal	Maximum Permissible Concentration (µg/l)
Pb	50
Mn	100
Cr	50
Cd	5
Zn	1500
Fe	300

ground surface. Based on the borehole TP6 location, we can conclude that the flow path of the contaminant species is dominantly towards the southeast of the study area.

Although the common practice of the waste disposal site on open land surface causes deterioration of groundwater quality, the distributions of the contaminants appears to be localized and confined within the dumping area and not diffused or dispersed over a wide area.

ACHNOWLEDGEMENT

The authors would like to thanks to the staffs of Nuclear Malaysia especially to Hj. Halim and Azwah for their full commitment particularly in preparing and analysing the samples.

REFERENCES

Alloway B.J., 1990. Heavy metals in soils. Blackie, London, 339 p.

Appelo, C.A.J. & Postma, D., 1996. Geochemistry, Groundwater and Pollution. Balkema, Rotterdam.

Engineering & Environmental Consultants, 1993. Preliminary Environmental Impact Assessment for the Development of a Sanitary Landfill for Majlis Perbandaran Taiping. Unpublished Report.

Engoebumi, 2003. Drilling and Construction of Wells at the Municipal Landfill site of Taiping, Perak. Unpublished Technical Report

Hani H., 1990. The analysis of inorganic and organic pollutants in soil with special regard to their bioavailability. Inter. J. Environ. Anal. Chem., 39(2), 197–208.

Mohd Tadza Abdul Rahman, Daud Mohamad, Abdul Rahim Samsudin & Tan Teong Hing, 1999. Migration of pollutants in groundwater at a domestic landfill in Malaysia. A case study: Pollutants distribution and groundwater quality. Computer Aided Workshop on Groundwater Contamination. 18-26, November 1999.

Mohd Tadza Abdul Rahman, 2001. Kajian Migrasi Bahan Pencemaran dan Kesannya ke Atas Sistem Air Tanah di Tapak Pelupusan Sisa Domestik Gemencheh, Negeri Sembilan dengan Paduan Kaedah Nuklear, Geofizik dan Hidrogeokimia. Unpublished Report.

Mohd Tadza Abdul Rahman, Kamarudin Samuding, Roslanzairi Mostapa, Ismail C. Mohamad, Ismail Abustan & Nabsiah Abdul Wahid, 2007. Investigation of pollutant flow pattern in groundwater system at Taiping municipal solid waste (msw) disposal site, Perak. National Geosciences Conference 2007, UMS, Sabah 7-9 Jun 2007.

Wan Ngah, W.S. & Hanafiah, M.A.K.M., 2008. Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: A Review. Journal of Bioresource Technology 99, 3935-3948.

Manuscript received: 25 May 2009